



Índice

1. algorithm	2
2. Estructuras	2
2.1. RMQ (static)	2
2.2. RMQ (dynamic)	2
2.3. Fenwick Tree	3
2.4. Union Find	3
2.5. Disjoint Intervals	3
2.6. RMQ (2D)	3
2.7. Big Int	4
2.8. Modnum	5
2.9. Bittrie	5
3. Strings	6
3.1. Trie	6
3.2. Suffix Array	6
3.3. String Matching With Suffix Array	6
3.4. LCP (Longest Common Prefix)	7
3.5. Corasick	7

4. Geometría	7
4.1. Punto	7
4.2. Line	8
4.3. Segment	8
4.4. Rectangle	8
4.5. Polygon Area	8
4.6. Circle	9
4.7. Point in Poly	9
4.8. Convex Check CHECK	9
4.9. Convex Hull	9
4.10. Cut Polygon	9
4.11. Bresenham	10
4.12. Rotate Matrix	10
5. Math	10
5.1. Exp. de Matrices en log(n)	10
5.2. Criba	10
5.3. Factorizacion	10
5.4. GCD	10
5.5. LCM	11
5.6. Simpson	11
5.7. Fraction	11
5.8. Polinomio	11
6. Grafos	12
6.1. Dijkstra	12
6.2. Bellman-Ford	12
6.3. Floyd-Warshall	12
6.4. 2-SAT + Tarjan SCC	12
6.5. Articulation Points	13
6.6. LCA + Climb	13
7. Network Flow	14
7.1. Edmonds Karp's	14
7.2. Push-Relabel	14
8. Ayudamemoria	15

## 1. algorithm

**#include <algorithm> #include <numeric>**

Algo	Params	Funcion
sort, stable_sort	f, l	ordena el intervalo
nth_element	f, nth, l	void ordena el n-esimo, y particiona el resto
fill, fill_n	f, l / n, elem	void llena [f, l) o [f, f+n) con elem
lower_bound, upper_bound	f, l, elem	it al primer / ultimo donde se puede insertar elem para que quede ordenada
binary_search	f, l, elem	bool esta elem en [f, l)
copy	f, l, resul	hace resul+i=f+i $\forall i$
find, find_if, find_first_of	f, l, elem / pred / f2, l2	it encuentra i $\in [f, l)$ tq. i=elem, pred(i), i $\in [f2, l2)$
count, count_if	f, l, elem/pred	cuenta elem, pred(i)
search	f, l, f2, l2	busca [f2, l2) $\in [f, l)$
replace, replace_if	f, l, old / pred, new	cambia old / pred(i) por new
reverse	f, l	da vuelta
partition, stable_partition	f, l, pred	pred(i) ad, !pred(i) atras
min_element, max_element	f, l, [comp]	it min, max de [f, l)
lexicographical_compare	f1, l1, f2, l2	bool con [f1, l1] i [f2, l2]
next/prev_permutation	f, l	deja en [f, l) la perm sig, ant
set_intersection, set_difference, set_union, set_symmetric_difference,	f1, l1, f2, l2, res	[res, ...) la op. de conj
push_heap, pop_heap, make_heap	f, l, e / e /	mete/saca e en heap [f, l), hace un heap de [f, l)
is_heap	f, l	bool es [f, l) un heap
accumulate	f, l, i, [op]	$T = \sum / \text{oper de } [f, l)$
inner_product	f1, l1, f2, i	$T = i + [f1, l1) \cdot [f2, \dots)$
partial_sum	f, l, r, [op]	$r+i = \sum / \text{oper de } [f, f+i) \forall i \in [f, l)$
__builtin_ffs	unsigned int	Pos. del primer 1 desde la derecha
__builtin_clz	unsigned int	Cant. de ceros desde la izquierda.
__builtin_ctz	unsigned int	Cant. de ceros desde la derecha.
__builtin_popcount	unsigned int	Cant. de 1's en x.
__builtin_parity	unsigned int	1 si x es par, 0 si es impar.
__builtin_XXXXXXll	unsigned ll	= pero para long long's.

## 2. Estructuras

### 2.1. RMQ (static)

Dado un arreglo y una operación asociativa idempotente, get(i, j) opera sobre el rango [i, j). Restricción: LVL  $\geq 2 \cdot \text{ceil}(\log n)$ ; Usar [ ] para llenar arreglo y luego build().

```

1 struct RMQ{
2     #define LVL 10
3     tipo vec[LVL][1<<(LVL+1)];
4     tipo &operator[] (int p){return vec[0][p];}
5     tipo get(int i, int j) { //intervalo [i,j)
6         int p = 31-__builtin_clz(j-i);
7         return min(vec[p][i], vec[p][j-(1<<p)]);
8     }
9     void build(int n) { //O(n log n)
10        int mp = 31-__builtin_clz(n);
11        forn(p, mp) forn(x, n-(1<<p))
12            vec[p+1][x] = min(vec[p][x], vec[p][x+(1<<p)]);
13    }
14 };

```

### 2.2. RMQ (dynamic)

```

1 //Dado un arreglo y una operacion asociativa con neutro, get(i, j) opera
   sobre el rango [i, j).
2 #define MAXN 100000
3 struct RMQ{
4     int sz;
5     tipo t[4*MAXN];
6     tipo &operator[] (int p){return t[sz+p];}
7     void init(int n){ //O(n log n)
8         sz = 1 << (32-__builtin_clz(n));
9         fill(t, t+2*sz, 0); // 0=elemento neutro
10    }
11    void updall(){ //O(n)
12        dforsn(i, 0, sz) t[i]=max(t[2*i], t[2*i+1]);}
13    tipo get(int i, int j){return get(i, j, 1, 0, sz);}
14    tipo get(int i, int j, int n, int a, int b){ //O(lgn)
15        if(j<=a || i>=b) return 0; //neutro
16        if(i<=a && b<=j) return t[n];
17        int c=(a+b)/2;
18        return max(get(i, j, 2*n, a, c), get(i, j, 2*n+1, c, b));

```

```

19 }
20 void set(int p, tipo val){//O(lgn)
21     for(p+=sz; p>0 && t[p]!=val;){
22         t[p]=val;
23         p/=2;
24         val=max(t[p*2], t[p*2+1]);
25     }
26 }
27 }rmq;
28 //Usage:
29 cin >> n; rmq.init(n); forn(i, n) cin >> rmq[i]; rmq.updall();

```

### 2.3. Fenwick Tree

```

1 //For 2D threat each column as a Fenwick tree, by adding a nested for in
  //each operation
2 struct Fenwick{
3     static const int sz=1000001;
4     tipo t[sz];
5     tipo sum(int a, int b){return sum(b)-sum(a-1);}
6     void adjust(int p, tipo v){//valid with p in [1, sz), O(lgn)
7         for(; p<sz; p+=(p&-p)) t[p]+=v; }
8     tipo sum(int p){//cumulative sum in [1, p], O(lgn)
9         tipo s=0;
10        for(; p; p-=(p&-p)) s+=t[p];
11        return s;
12    }
13    //get largest value with cumulative sum less than or equal to x;
14    //for smallest, pass x-1 and add 1 to result
15    int getind(tipo x) {//O(lgn)
16        int idx = 0, mask = N;
17        while(mask && idx < N) {
18            int t = idx + mask;
19            if(x >= tree[t])
20                idx = t, x -= tree[t];
21            mask >>= 1;
22        }
23        return idx;
24    }
25 };

```

### 2.4. Union Find

```

1 struct UnionFind{

```

```

2     vector<int> f;//the array contains the parent of each node
3     void init(int n){f.clear(); f.insert(f.begin(), n, -1);}
4     int comp(int x){return (f[x]==-1?x:f[x]=comp(f[x]));} //O(1)
5     bool join(int i, int j) {
6         bool con=comp(i)==comp(j);
7         if(!con) f[comp(i)] = comp(j);
8         return con;
9     }
10 };

```

### 2.5. Disjoint Intervals

```

1 bool operator< (const ii &a, const ii &b) {return a.fst<b.fst;}
2 //Stores intervals as [first, second]
3 //in case of a collision it joins them in a single interval
4 struct disjoint_intervals {
5     set<ii> segs;
6     void insert(ii v) {//O(lgn)
7         if(v.snd-v.fst==0.) return;//OJO
8         set<ii>::iterator it,at;
9         at = it = segs.lower_bound(v);
10        if (at!=segs.begin() && (--at)->snd >= v.fst)
11            v.fst = at->fst, --it;
12        for(; it!=segs.end() && it->fst <= v.snd; segs.erase(it++))
13            v.snd=max(v.snd, it->snd);
14        segs.insert(v);
15    }
16 };

```

### 2.6. RMQ (2D)

```

1 struct RMQ2D{
2     static const int sz=1024;
3     RMQ t[sz];
4     RMQ &operator[] (int p){return t[sz/2+p];}
5     void build(int n, int m){//O(nm)
6         forr(y, sz/2, sz/2+m)
7             t[y].build(m);
8         forr(y, sz/2+m, sz)
9             forn(x, sz)
10                t[y].t[x]=0;
11        dforn(y, sz/2)
12            forn(x, sz)
13                t[y].t[x]=max(t[y*2].t[x], t[y*2+1].t[x]);

```

```

14 }
15 void set(int x, int y, tipo v){//O(lgm.lgn)
16     y+=sz/2;
17     t[y].set(x, v);
18     while(y/=2)
19         t[y].set(x, max(t[y*2][x], t[y*2+1][x]));
20 }
21 //O(lgm.lgn)
22 int get(int x1, int y1, int x2, int y2, int n=1, int a=0, int b=sz/2){
23     if(y2<=a || y1>=b) return 0;
24     if(y1<=a && b<=y2) return t[n].get(x1, x2);
25     int c=(a+b)/2;
26     return max(get(x1, y1, x2, y2, 2*n, a, c),
27               get(x1, y1, x2, y2, 2*n+1, c, b));
28 }
29 };
30 //Example to initialize a grid of M rows and N columns:
31 RMQ2D rmq;
32 forn(i, M)
33     forn(j, N)
34         cin >> rmq[i][j];
35 rmq.build(N, M);

```

## 2.7. Big Int

```

1 #define BASEXP 6
2 #define BASE 1000000
3 #define LMAX 1000
4 struct bint{
5     int l;
6     tipo n[LMAX];
7     bint(tipo x=0){
8         l=0;
9         forn(i, LMAX){
10             n[i]=x%BASE;
11             x/=BASE;
12             l+=!!x||!i;
13         }
14     }
15     bint(string x){
16         l=(x.size()-1)/BASEXP+1;
17         fill(n, n+LMAX, 0);
18         tipo r=1;

```

```

19         forn(i, sz(x)){
20             n[i / BASEXP] += r * (x[x.size()-1-i]-'0');
21             r*=10; if(r==BASE)r=1;
22         }
23     }
24     void out(){
25         cout << n[l-1];
26         dforsn(i, 0, l-1) printf("%6.11u", n[i]);//6=BASEXP!
27     }
28     void invar(){
29         fill(n+1, n+LMAX, 0);
30         while(l>1 && !n[l-1]) l--;
31     }
32 };
33 bint operator+(const bint&a, const bint&b){
34     bint c;
35     c.l = max(a.l, b.l);
36     tipo q = 0;
37     forn(i, c.l) q += a.n[i]+b.n[i], c.n[i]=q %BASE, q/=BASE;
38     if(q) c.n[c.l++] = q;
39     c.invar();
40     return c;
41 }
42 pair<bint, bool> lresta(const bint&a, const bint&b) // c = a - b
43 {
44     bint c;
45     c.l = max(a.l, b.l);
46     tipo q = 0;
47     forn(i, c.l) q += a.n[i]-b.n[i], c.n[i]=(q+BASE) %BASE, q=(q+BASE)/
48         BASE-1;
49     c.invar();
50     return make_pair(c, !q);
51 }
52 bint& operator-= (bint&a, const bint&b){return a=lresta(a, b).first;}
53 bint operator- (const bint&a, const bint&b){return lresta(a, b).first;}
54 bool operator< (const bint&a, const bint&b){return !lresta(a, b).second;
55 }
56 bool operator<= (const bint&a, const bint&b){return lresta(b, a).second;
57 }
58 bool operator==(const bint&a, const bint&b){return a <= b && b <= a;}
59 bint operator*(const bint&a, tipo b){
60     bint c;
61     tipo q = 0;

```

```

59     forn(i, a.l) q += a.n[i]*b, c.n[i] = q %BASE, q/=BASE;
60     c.l = a.l;
61     while(q) c.n[c.l++] = q %BASE, q/=BASE;
62     c.invar();
63     return c;
64 }
65 bint operator*(const bint&a, const bint&b){
66     bint c;
67     c.l = a.l+b.l;
68     fill(c.n, c.n+b.l, 0);
69     forn(i, a.l){
70         tipo q = 0;
71         forn(j, b.l) q += a.n[i]*b.n[j]+c.n[i+j], c.n[i+j] = q %BASE, q
            /=BASE;
72         c.n[i+b.l] = q;
73     }
74     c.invar();
75     return c;
76 }
77 pair<bint, tipo> ldiv(const bint& a, tipo b){// c = a / b ; rm = a % b
78     bint c;
79     tipo rm = 0;
80     dforsn(i, 0, a.l){
81         rm = rm * BASE + a.n[i];
82         c.n[i] = rm / b;
83         rm %= b;
84     }
85     c.l = a.l;
86     c.invar();
87     return make_pair(c, rm);
88 }
89 bint operator/(const bint&a, tipo b){return ldiv(a, b).first;}
90 tipo operator%(const bint&a, tipo b){return ldiv(a, b).second;}
91 pair<bint, bint> ldiv(const bint& a, const bint& b){
92     bint c;
93     bint rm = 0;
94     dforsn(i, 0, a.l){
95         if (rm.l==1 && !rm.n[0])
96             rm.n[0] = a.n[i];
97         else{
98             dforsn(j, 0, rm.l) rm.n[j+1] = rm.n[j];
99             rm.n[0] = a.n[i];
100             rm.l++;

```

```

101     }
102     tipo q = rm.n[b.l] * BASE + rm.n[b.l-1];
103     tipo u = q / (b.n[b.l-1] + 1);
104     tipo v = q / b.n[b.l-1] + 1;
105     while (u < v-1){
106         tipo m = (u+v)/2;
107         if (b*m <= rm) u = m;
108         else v = m;
109     }
110     c.n[i]=u;
111     rm-=b*u;
112 }
113 c.l=a.l;
114 c.invar();
115 return make_pair(c, rm);
116 }
117 bint operator/(const bint&a, const bint&b){return ldiv(a, b).first;}
118 bint operator%(const bint&a, const bint&b){return ldiv(a, b).second;}

```

## 2.8. Modnum

```

1 struct mnum{
2     static const tipo mod=12582917;
3     tipo v;
4     mnum(tipo v=0): v(v%mod) {}
5     mnum operator+(mnum b){return v+b.v;}
6     mnum operator-(mnum b){return v>=b.v? v-b.v : mod-b.v+v;}
7     mnum operator*(mnum b){return v*b.v;}
8     mnum operator^(int n){
9         if(!n) return 1;
10        return n%2? (*this)^(n/2)*(*this) : (*this)^(n/2);}
11 };

```

## 2.9. Bittrie

```

1 struct bitrie{
2     static const int sz=1<<5;//5=ceil(log(n))
3     int V;//valor del nodo
4     vector<bitrie> ch;//childs
5     bitrie():V(0){} //NEUTRO
6     void set(int p, int v, int bit=sz>>1){//0(log sz)
7         if(bit){
8             ch.resize(2);
9             ch[(p&bit)>0].set(p, v, bit>>1);

```

```

10     V=max(ch[0].V, ch[1].V);
11 }
12 else V=v;
13 }
14 int get(int i, int j, int a=0, int b=sz){//O(log sz)
15     if(j<=a || i>=b) return 0;//NEUTRO
16     if(i<=a && b<=j) return V;
17     if(!sz(ch)) return V;
18     int c=(a+b)/2;
19     return max(ch[0].get(i, j, a, c), ch[1].get(i, j, c, b));
20 }
21 };

```

### 3. Strings

#### 3.1. Trie

```

1 struct trie{
2     map<char, trie> m;
3     void add(const string &s, int p=0){
4         if(s[p]) m[s[p]].add(s, p+1);
5     }
6     void dfs(){
7         //Do stuff
8         forall(it, m)
9             it->second.dfs();
10    }
11 };

```

#### 3.2. Suffix Array

```

1 #define MAX_N 1000
2 #define RABOUND(x) (x<n? RA[x] : 0)
3 //SA will hold the suffixes in order.
4 int SA[MAX_N], RA[MAX_N], n;
5 string s; //input string, n=sz(s)
6
7 void countingSort(int k){
8     int f[MAX_N], tmpSA[MAX_N];
9     zero(f);
10    forn(i, n) f[RABOUND(i+k)]++;
11    int sum=0;
12    forn(i, max(255, n)){

```

```

13        int t=f[i]; f[i]=sum; sum+=t;}
14    forn(i, n)
15        tmpSA[f[RABOUND(SA[i]+k)]++] = SA[i];
16    memcpy(SA, tmpSA, sizeof(SA));
17 }
18 void constructSA(){//O(n log n)
19     n=sz(s);
20     forn(i, n) SA[i]=i, RA[i]=s[i];
21     for(int k=1; k<n; k<=<1){
22         countingSort(k), countingSort(0);
23         int r, tmpRA[MAX_N];
24         tmpRA[SA[0]]=r=0;
25         forr(i, 1, n)
26             tmpRA[SA[i]]=(RA[SA[i]]==RA[SA[i-1]] && RA[SA[i]+k]==RA[SA[i-1]+k])? r : ++r;
27         memcpy(RA, tmpRA, sizeof(RA));
28         if(RA[SA[n-1]]==n-1) break;
29     }
30 }
31 void print(){//for debug
32     forn(i, n)
33         cout << i << ' ' <<
34         s.substr(SA[i], s.find( '$', SA[i])-SA[i]) << endl;}

```

#### 3.3. String Matching With Suffix Array

```

1 //returns (lowerbound, upperbound) of the search
2 ii stringMatching(string P){ //O(sz(P)lgn)
3     int lo=0, hi=n-1, mid=lo;
4     while(lo<hi){
5         mid=(lo+hi)/2;
6         int res=s.compare(SA[mid], sz(P), P);
7         if(res>=0) hi=mid;
8         else lo=mid+1;
9     }
10    if(s.compare(SA[lo], sz(P), P)!=0) return ii(-1, -1);
11    ii ans; ans.fst=lo;
12    lo=0, hi=n-1, mid;
13    while(lo<hi){
14        mid=(lo+hi)/2;
15        int res=s.compare(SA[mid], sz(P), P);
16        if(res>0) hi=mid;
17        else lo=mid+1;

```

```

18 }
19 if(s.compare(SA[hi], sz(P), P)!=0) hi--;
20 ans.snd=hi;
21 return ans;
22 }

```

### 3.4. LCP (Longest Common Prefix)

```

1 //Calculates the LCP between consecutives suffixes in the Suffix Array.
2 //LCP[i] is the length of the LCP between SA[i] and SA[i-1]
3 int LCP[MAX_N];
4 void computeLCP(){//O(n)
5     int phi[MAX_N], PLCP[MAX_N];
6     phi[SA[0]]=-1;
7     forr(i, 1, n) phi[SA[i]]=SA[i-1];
8     int L=0;
9     forn(i, n){
10         if(phi[i]==-1) {PLCP[i]=0; continue;}
11         while(s[i+L]==s[phi[i]+L]) L++;
12         PLCP[i]=L;
13         L=max(L-1, 0);
14     }
15     forn(i, n) LCP[i]=PLCP[SA[i]];
16 }

```

### 3.5. Corasick

```

1
2 struct trie{
3     map<char, trie> next;
4     trie* tran[256]; //transiciones del automata
5     int idhoja, szhoja; //id de la hoja o 0 si no lo es
6     //link lleva al sufijo mas largo, nxthoja lleva al mas largo pero que
7     //es hoja
8     trie *padre, *link, *nxthoja;
9     char pch; //caracter que conecta con padre
10    trie(): tran(), idhoja(), padre(), link() {}
11    void insert(const string &s, int id=1, int p=0){ //id>0!!!
12        if(p<sz(s)){
13            trie &ch=next[s[p]];
14            tran[(int)s[p]]=&ch;
15            ch.padre=this, ch.pch=s[p];
16            ch.insert(s, id, p+1);
17        }
18    }
19 }

```

```

17     else idhoja=id, szhoja=sz(s);
18 }
19 trie* get_link() {
20     if(!link){
21         if(!padre) link=this; //es la raiz
22         else if(!padre->padre) link=padre; //hijo de la raiz
23         else link=padre->get_link()->get_tran(pch);
24     }
25     return link;
26 }
27 trie* get_tran(int c) {
28     if(!tran[c])
29         tran[c] = !padre? this : this->get_link()->get_tran(c);
30     return tran[c];
31 }
32 trie *get_nxthoja(){
33     if(!nxthoja) nxthoja = get_link()->idhoja? link : link->nxthoja;
34     return nxthoja;
35 }
36 void print(int p){
37     if(idhoja)
38         cout << "found" << idhoja << " at position" << p-szhoja << endl;
39     ;
40     if(get_nxthoja()) get_nxthoja()->print(p);
41 }
42 void matching(const string &s, int p=0){
43     print(p);
44     if(p<sz(s)) get_tran(s[p])->matching(s, p+1);
45 }

```

## 4. Geometría

#define EPS 1e-9

### 4.1. Punto

```

1 struct pto{
2     tipo x, y;
3     pto(tipo x=0, tipo y=0):x(x),y(y){}
4     pto operator+(pto a){return pto(x+a.x, y+a.y);}
5     pto operator-(pto a){return pto(x-a.x, y-a.y);}
6     pto operator+(tipo a){return pto(x+a, y+a);}
7     pto operator*(tipo a){return pto(x*a, y*a);}
8     pto operator/(tipo a){return pto(x/a, y/a);}
9 }

```



```

9 //dot product, producto interno:
10 tipo operator*(pto a){return x*a.x+y*a.y;}
11 //module of the cross product or vectorial product:
12 //if a is less than 180 clockwise from b, a^b>0
13 tipo operator^(pto a){return x*a.y-y*a.x;}
14 //returns true if this is at the left side of line qr
15 bool left(pto q, pto r){return ((q-*this)^(r-*this))>0;}
16 bool operator<(const pto &a) const{return x<a.x || (abs(x-a.x)<EPS &&
    y<a.y);}
17 bool operator==(pto a){return abs(x-a.x)<EPS && abs(y-a.y)<EPS;}
18 double norm(){return sqrt(x*x+y*y);}
19 tipo norm_sq(){return x*x+y*y;}
20 };
21 double dist(pto a, pto b){return (b-a).norm();}
22 typedef pto vec;
23
24 double angle(pto a, pto o, pto b){
25     vec oa=a-o, ob=b-o;
26     return acos((oa*ob) / sqrt(oa.norm_sq()*ob.norm_sq()));}
27
28 //rotate p by theta rads CCW w.r.t. origin (0,0)
29 pto rotate(pto p, double theta){
30     return pto(p.x*cos(theta)-p.y*sin(theta),
31         p.x*sin(theta)+p.y*cos(theta));
32 }

```

## 4.2. Line

```

1 struct line{
2     line() {}
3     double a,b,c;//Ax+By=C
4     //pto MUST store float coordinates!
5     line(double a, double b, double c):a(a),b(b),c(c){}
6     line(pto p, pto q): a(q.y-p.y), b(p.x-q.x), c(a*p.x+b*p.y) {}
7 };
8 bool parallels(line l1, line l2){return abs(l1.a*l2.b-l2.a*l1.b)<EPS;}
9 pto inter(line l1, line l2){//intersection
10     double det=l1.a*l2.b-l2.a*l1.b;
11     if(abs(det)<EPS) return pto(INF, INF);//parallels
12     return pto(l2.b*l1.c-l1.b*l2.c, l1.a*l2.c-l2.a*l1.c)/det;
13 }

```

## 4.3. Segment

```

1 struct segm{
2     pto s,f;
3     segm(pto s, pto f):s(s), f(f) {}
4     pto closest(pto p) {//use for dist to point
5         double l2 = dist_sq(s, f);
6         if(l2==0.) return s;
7         double t=((p-s)*(f-s))/l2;
8         if (t<0.) return s;//not write if is a line
9         else if(t>1.)return f;//not write if is a line
10        return s+((f-s)*t);
11    }
12    bool inside(pto p){
13        return ((s-p)^(f-p))==0 && min(s, f)<*this&&*this<max(s, f);}
14    };
15
16    bool insidebox(pto a, pto b, pto p) {
17        return (a.x-p.x)*(p.x-b.x)>-EPS && (a.y-p.y)*(p.y-b.y)>-EPS;
18    }
19    pto inter(segm s1, segm s2){
20        pto r=inter(line(s1.s, s1.f), line(s2.s, s2.f));
21        if(insidebox(s1.s,s1.f,p) && insidebox(s2.s,s2.f,p))
22            return r;
23        return pto(INF, INF);
24    }

```

## 4.4. Rectangle

```

1 struct rect{
2     //lower-left and upper-right corners
3     pto lw, up;
4 };
5 //returns if there's an intersection and stores it in r
6 bool inter(rect a, rect b, rect &r){
7     r.lw=pto(max(a.lw.x, b.lw.x), max(a.lw.y, b.lw.y));
8     r.up=pto(min(a.up.x, b.up.x), min(a.up.y, b.up.y));
9     //check case when only a edge is common
10    return r.lw.x<r.up.x && r.lw.y<r.up.y;
11 }

```

## 4.5. Polygon Area

```

1 double area(vector<tipo> &p){//0(sz(p))
2     double area=0;
3     forn(i, sz(p)) area+=p[i]^p[(i+1)%sz(p)];

```



```

4 //if points are in clockwise order then area is negative
5 return abs(area)/2;
6 }
7 //Area ellipse = M_PI*a*b where a and b are the semi axis lengths
8 //Area triangle = sqrt(s*(s-a)(s-b)(s-c)) where s=(a+b+c)/2

```

#### 4.6. Circle

```

1 vec perp(vec v){return vec(-v.y, v.x);}
2 line bisector(pto x, pto y){
3     line l=line(x, y); pto m=(x+y)/2;
4     return line(-l.b, l.a, -l.b*m.x+l.a*m.y);
5 }
6 struct Circle{
7     pto o;
8     double r;
9     //circle determined by three points, uses line
10    Circle(pto x, pto y, pto z){
11        o=inter(bisector(x, y), bisector(y, z));
12        r=dist(o, x);
13    }
14    pair<pto, pto> ptosTang(pto p){
15        pto m=(p+o)/2;
16        tipo d=dist(o, m);
17        tipo a=r*r/(2*d);
18        tipo h=sqrt(r*r-a*a);
19        pto m2=o+(m-o)*a/d;
20        vec per=perp(m-o)/d;
21        return mkp(m2-per*h, m2+per*h);
22    }
23 };
24 //finds the center of the circle containing p1 and p2 with radius r
25 //as there may be two solutions swap p1, p2 to get the other
26 bool circle2PtsRad(pto p1, pto p2, double r, pto &c){
27     double d2=(p1-p2).norm_sq(), det=r*r/d2-0.25;
28     if(det<0) return false;
29     c=(p1+p2)/2+perp(p2-p1)*sqrt(det);
30     return true;
31 }

```

#### 4.7. Point in Poly

```

1 //checks if v is inside of P, using ray casting
2 //works with convex and concave.

```

```

3 //excludes boundaries, handle it separately using segment.inside()
4 bool inPolygon(pto v, vector<pto>& P) {
5     bool c = false;
6     forn(i, sz(P)){
7         int j=(i+1)%sz(P);
8         if((P[j].y>v.y) != (P[i].y > v.y) &&
9         (v.x < (P[i].x - P[j].x) * (v.y-P[j].y) / (P[i].y - P[j].y) + P[j].x))
10            c = !c;
11     }
12     return c;
13 }

```

#### 4.8. Convex Check CHECK

```

1 bool isConvex(vector<int> &p){//O(N)
2     int N=sz(p);
3     if(N<3) return false;
4     bool isLeft=p[0].left(p[1], p[2]);
5     forr(i, 1, N)
6         if(p[i].left(p[(i+1)%N], p[(i+2)%N])!=isLeft)
7             return false;
8     return true; }

```

#### 4.9. Convex Hull

```

1 //stores convex hull of P in S, CCW order
2 void CH(vector<pto>& P, vector<pto> &S){
3     S.clear();
4     sort(P.begin(), P.end());
5     forn(i, sz(P)){
6         while(sz(S)>= 2 && S[sz(S)-1].left(S[sz(S)-2], P[i])) S.pop_back();
7         S.pb(P[i]);
8     }
9     S.pop_back();
10    int k=sz(S);
11    dforn(i, sz(P)){
12        while(sz(S) >= k+2 && S[sz(S)-1].left(S[sz(S)-2], P[i])) S.pop_back
13            ();
14        S.pb(P[i]);
15    }
16    S.pop_back();

```

#### 4.10. Cut Polygon

```

1 //cuts polygon Q along the line ab
2 //stores the left side (swap a, b for the right one) in P
3 void cutPolygon(pto a, pto b, vector<pto> Q, vector<pto> &P){
4     P.clear();
5     forn(i, sz(Q)){
6         double left1=(b-a)^(Q[i]-a), left2=(b-a)^(Q[(i+1)%sz(Q)]-a);
7         if(left1>=0) P.pb(Q[i]);
8         if(left1*left2<0)
9             P.pb(inter(line(Q[i], Q[(i+1)%sz(Q)]), line(a, b)));
10    }
11 }

```

#### 4.11. Bresenham

```

1 //plot a line approximation in a 2d map
2 void bresenham(pto a, pto b){
3     pto d=b-a; d.x=abs(d.x), d.y=abs(d.y);
4     pto s(a.x<b.x? 1: -1, a.y<b.y? 1: -1);
5     int err=d.x-d.y;
6     while(1){
7         m[a.x][a.y]=1;//plot
8         if(a==b) break;
9         int e2=2*err;
10        if(e2 > -d.y){
11            err-=d.y, a.x+=s.x;
12        }
13        if(e2 < d.x)
14            err+= d.x, a.y+= s.y;
15    }
16 }

```

#### 4.12. Rotate Matrix

```

1 //rotates matrix t 90 degrees clockwise
2 //using auxiliary matrix t2(faster)
3 void rotate(){
4     forn(x, n) forn(y, n)
5         t2[n-y-1][x]=t[x][y];
6     memcpy(t, t2, sizeof(t));
7 }

```

## 5. Math

### 5.1. Exp. de Matrices en log(n)

```

1 struct M22{      // |a b|
2     double a,b,c,d;// |c d|
3     M22 operator*(const M22 &p) const {
4         return (M22){a*p.a+b*p.c, a*p.b+b*p.d, c*p.a+d*p.c,c*p.b+d*p.d};}
5 };
6 M22 operator^(const M22 &p, int n){
7     if(!n) return (M22){1, 0, 0, 1}; //identidad
8     M22 q=p^(n/2); q=q*q;
9     return n%2? p * q : q;}

```

### 5.2. Criba

```

1 #define MAXP 80000 //no necesariamente primo
2 int criba[MAXP+1];
3 vector<int> primos;
4
5 void buscarprimos(){
6     forr(p, 2, MAXP+1) if(!criba[p]){
7         primos.push_back(p);
8         for(int m=2*p; m<=MAXP; m+=p) //borro los multiples de p
9             if(!criba[m]) criba[m]=p;
10    }
11 }

```

### 5.3. Factorizacion

Sea  $n = \prod p_i^{k_i}$ , fact(n) genera un map donde a cada  $p_i$  le asocia su  $k_i$

```

1 //factoriza bien numeros hasta (maximo primo)^2
2 map<ll,ll> fact(ll n){
3     map<ll,ll> ret;
4     forall(p, primos){
5         while(!(n%p)){
6             ret[*p]++; //divisor found
7             n/=p;
8         }
9     }
10    if(n>1) ret[n]++;
11    return ret;
12 }

```

### 5.4. GCD

```

1 tipo gcd(tipo a, tipo b){return a?gcd(b %a, a):b;}

```

## 5.5. LCM

```
1 | tipo lcm(tipo a, tipo b){return a / gcd(a,b) * b;}
```

## 5.6. Simpson

```
1 | double integral(double a, double b, int n=10000) {//0(n), n=cantdiv
2 |   double area=0, h=(b-a)/n, fa=f(a), fb;
3 |   for(i, n){
4 |     fb=f(a+h*(i+1));
5 |     area+=fa+ 4*f(a+h*(i+0.5)) +fb, fa=fb;
6 |   }
7 |   return area*h/6.;}
```

## 5.7. Fraction

```
1 | struct frac{
2 |   tipo p,q;
3 |   frac(tipo p=0, tipo q=1):p(p),q(q) {norm();}
4 |   tipo mcd(tipo a, tipo b){return a?mcd(b %a, a):b;}
5 |   void norm(){
6 |     tipo a = mcd(p,q);
7 |     if(a) p/=a, q/=a;
8 |     else q=1;
9 |     if (q<0) q=-q, p=-p;}
10 |   frac operator+(const frac& o){
11 |     tipo a = mcd(q,o.q);
12 |     return frac(p*(o.q/a)+o.p*(q/a), q*(o.q/a));}
13 |   frac operator-(const frac& o){
14 |     tipo a = mcd(q,o.q);
15 |     return frac(p*(o.q/a)-o.p*(q/a), q*(o.q/a));}
16 |   frac operator*(frac o){
17 |     tipo a = mcd(q,o.q), b = mcd(o.p,p);
18 |     return frac((p/b)*(o.p/a), (q/a)*(o.q/b));}
19 |   frac operator/(frac o){
20 |     tipo a = mcd(q,o.q), b = mcd(o.p,p);
21 |     return frac((p/b)*(o.q/a), (q/a)*(o.p/b));}
22 |   bool operator<(frac o){return (*this-o).p<0;}
23 |   bool operator==(frac o){return p==o.p&&q==o.q;}
24 | };
```

## 5.8. Polinomio

```
1 | #define MAX_GR 20
```

```
2 | struct poly {
3 |   tipo p[MAX_GR];//guarda los coeficientes del polinomio
4 |   poly(){zero(p);}
5 |   int gr()//calculates grade of the polynomial
6 |     dform(i,MAX_GR) if(p[i]) return i;
7 |     return 0; }
8 |   bool isnull() {return gr()==0 && !p[0];}
9 |   poly operator+(poly b) // - is analogous
10 |     poly c=THIS;
11 |     for(i,MAX_GR) c.p[i]+=b.p[i];
12 |     return c;
13 | }
14 | poly operator*(poly b) {
15 |   poly c;
16 |   for(i,MAX_GR) for(k,i+1) c.p[i]+=p[k]*b.p[i-k];
17 |   return c;
18 | }
19 | tipo eval(tipo v) {
20 |   tipo sum = 0;
21 |   dforsn(i, 0, MAX_GR) sum=sum*v + p[i];
22 |   return sum;
23 | }
24 | //the following function generates the roots of the polynomial
25 | //it can be easily modified to return float roots
26 | set<tipo> roots(){
27 |   set<tipo> roots;
28 |   tipo a0 = abs(p[0]), an = abs(p[gr()]);
29 |   vector<tipo> ps,qs;
30 |   forr(p,1,sqrt(a0)+1) if (a0%p==0) ps.pb(p),ps.pb(a0/p);
31 |   forr(q,1,sqrt(an)+1) if (an%q==0) qs.pb(q),qs.pb(an/q);
32 |   forall(pt,ps)
33 |     forall(qt,qs) if ( (*pt) % (*qt)==0 ) {
34 |       tipo root = abs((*pt) / (*qt));
35 |       if (eval(root)==0) roots.insert(root);
36 |     }
37 |   return roots;
38 | }
39 | };
40 | //the following functions allows parsing an expression like
41 | //34+150+4*45
42 | //into a polynomial(el numero en funcion de la base)
43 | #define LAST(s) (sz(s)? s[sz(s)-1] : 0)
44 | #define POP(s) s.erase(--s.end());
```

```

45 poly D(string &s) {
46     poly d;
47     for(int i=0; isdigit(LAST(s)); i++) d.p[i]=LAST(s)-'0', POP(s);
48     return d;}
49
50 poly T(string &s) {
51     poly t=D(s);
52     if (LAST(s)=='*'){POP(s); return T(s)*t;}
53     return t;
54 }
55 //main function, call this to parse
56 poly E(string &s) {
57     poly e=T(s);
58     if (LAST(s)=='+'){POP(s); return E(s)+e;}
59     return e;
60 }

```

## 6. Grafos

### 6.1. Dijkstra

```

1  #define INF 1e9
2  int N;
3  #define MAX_V 250001
4  vector<ii> G[MAX_V];
5  //To add an edge use
6  #define add(a, b, w) G[a].pb(mkp(w, b))
7
8  ll dijkstra(int s, int t){//O(|E| log |V|)
9      priority_queue<ii, vector<ii>, greater<ii> > Q;
10     vector<ll> dist(N, INF); vector<int> dad(N, -1);
11     Q.push(mkp(0, s)); dist[s] = 0;
12     while(sz(Q)){
13         ii p = Q.top(); Q.pop();
14         if(p.snd == t) break;
15         forall(it, G[p.snd])
16             if(dist[p.snd]+it->first < dist[it->snd]){
17                 dist[it->snd] = dist[p.snd] + it->fst;
18                 dad[it->snd] = p.snd;
19                 Q.push(mkp(dist[it->snd], it->snd));
20             }
21     }
22     return dist[t];

```

```

23     if(dist[t]<INF)//path generator
24     for(int i=t; i!=-1; i=dad[i])
25         printf("%d%c", i, (i==s?'n':' '));
26 }

```

### 6.2. Bellman-Ford

```

1  vector<ii> G[MAX_N]; //ady. list with pairs (weight, dst)
2  int dist[MAX_N];
3  void bford(int src){//O(VE)
4      dist[src]=0;
5      forn(i, N-1) forn(j, N) if(dist[j]!=INF) forall(it, G[j])
6          dist[it->snd]=min(dist[it->snd], dist[j]+it->fst);
7  }
8
9  bool hasNegCycle(){
10     forn(j, N) if(dist[j]!=INF) forall(it, G[j])
11         if(dist[it->snd]>dist[j]+it->fst) return true;
12     //inside if: all points reachable from it->snd will have -INF distance
13     // (do bfs)
14     return false;
15 }

```

### 6.3. Floyd-Warshall

```

1  //G[i][j] contains weight of edge (i, j) or INF
2  //G[i][i]=0
3  int G[MAX_N][MAX_N];
4  void floyd(){//O(N^3)
5      forn(k, N) forn(i, N) if(G[i][k]!=INF) forn(j, N) if(G[k][j]!=INF)
6          G[i][j]=min(G[i][j], G[i][k]+G[k][j]);
7  }
8  bool inNegCycle(int v){
9      return G[v][v]<0;}
10 //checks if there's a neg. cycle in path from a to b
11 bool hasNegCycle(int a, int b){
12     forn(i, N) if(G[a][i]!=INF && G[i][i]<0 && G[i][b]!=INF)
13         return true;
14     return false;
15 }

```

### 6.4. 2-SAT + Tarjan SCC

```

1  //We have a vertex representing a var and other for his negation.

```

```

2 //Every edge stored in G represents an implication. To add an equation
  of the form a||b, use addor(a, b)
3 //MAX=max cant var, n=cant var
4 #define addor(a, b) (G[neg(a)].pb(b), G[neg(b)].pb(a))
5 vector<int> G[MAX*2];
6 //idx[i]=index assigned in the dfs
7 //lw[i]=lowest index(closer from the root) reachable from i
8 int lw[MAX*2], idx[MAX*2], qidx;
9 stack<int> q;
10 int qcmp, cmp[MAX*2];
11 //verdad[cmp[i]]=valor de la variable i
12 bool verdad[MAX*2+1];
13
14 int neg(int x) { return x>=n? x-n : x+n;}
15 void tjn(int v){
16     lw[v]=idx[v]++qidx;
17     q.push(v), cmp[v]=-2;
18     forall(it, G[v]){
19         if(!idx[*it] || cmp[*it]==-2){
20             if(!idx[*it]) tjn(*it);
21             lw[v]=min(lw[v], lw[*it]);
22         }
23     }
24     if(lw[v]==idx[v]){
25         qcmp++;
26         int x;
27         do{x=q.top(); q.pop(); cmp[x]=qcmp;}while(x!=v);
28         verdad[qcmp]=(cmp[neg(v)]<0);
29     }
30 }
31 //remember to CLEAR G!!!
32 bool satisf(){//O(n)
33     memset(idx, 0, sizeof(idx)), qidx=0;
34     memset(cmp, -1, sizeof(cmp)), qcmp=0;
35     forn(i, n){
36         if(!idx[i]) tjn(i);
37         if(!idx[neg(i)]) tjn(neg(i));
38     }
39     forn(i, n) if(cmp[i]==cmp[neg(i)]) return false;
40     return true;
41 }

```

## 6.5. Articulation Points

```

1 int N;
2 vector<int> G[1000000];
3 //V[i]=node number(if visited), L[i]= lowest V[i] reachable from i
4 int qV, V[1000000], L[1000000], P[1000000];
5 void dfs(int v, int f){
6     L[v]=V[v]++qV;
7     forall(it, G[v])
8         if(!V[*it]){
9             dfs(*it, v);
10            L[v] = min(L[v], L[*it]);
11            P[v]+= L[*it]>=V[v];
12        }
13        else if(*it!=f)
14            L[v]=min(L[v], V[*it]);
15    }
16    int cantart(){ //O(n)
17        qV=0;
18        zero(V), zero(P);
19        dfs(1, 0); P[1]--;
20        int q=0;
21        forn(i, N) if(P[i]) q++;
22    return q;
23 }

```

## 6.6. LCA + Climb

```

1 //f[v][k] holds the 2^k father of v
2 //L[v] holds the level of v
3 int N, f[100001][20], L[100001];
4 void build(){//f[i][0] must be filled previously, O(nlgn)
5     forn(k, 20-1) forn(i, N) f[i][k+1]=f[f[i][k]][k];}
6
7 #define lg(x) (31-__builtin_clz(x))//=floor(log2(x))
8
9 int climb(int a, int d){//O(lgn)
10     if(!d) return a;
11     dfor(i, lg(L[a])+1)
12         if(1<=i<=d)
13             a=f[a][i], d-=1<=i;
14     return a;
15 }
16 int lca(int a, int b){//O(lgn)
17     if(L[a]<L[b]) swap(a, b);

```

```

18 a=climb(a, L[a]-L[b]);
19 if(a==b) return a;
20 dform(i, lg(L[a])+1)
21     if(f[a][i]!=f[b][i])
22         a=f[a][i], b=f[b][i];
23 return f[a][0];
24 }

```

## 7. Network Flow

### 7.1. Edmonds Karp's

```

1 #define MAX_V 1000
2 #define INF 1e9
3 //special nodes
4 #define SRC 0
5 #define SNK 1
6 map<int, int> G[MAX_V]; //limpiar esto
7 //To add an edge use
8 #define add(a, b, w) G[a][b]=w
9 int f, p[MAX_V];
10 void augment(int v, int minE){
11     if(v==SRC) f=minE;
12     else if(p[v]!=-1){
13         augment(p[v], min(minE, G[p[v]][v]));
14         G[p[v]][v]-=f, G[v][p[v]]+=f;
15     }
16 }
17 ll maxflow(){//O(VE^2)
18     ll Mf=0;
19     do{
20         f=0;
21         char used[MAX_V]; queue<int> q; q.push(SRC);
22         zero(used), memset(p, -1, sizeof(p));
23         while(sz(q)){
24             int u=q.front(); q.pop();
25             if(u==SNK) break;
26             forall(it, G[u])
27                 if(it->snd>0 && !used[it->fst])
28                     used[it->fst]=true, q.push(it->fst), p[it->fst]=u;
29         }
30         augment(SNK, INF);
31         Mf+=f;

```

```

32 }while(f);
33 return Mf;
34 }

```

### 7.2. Push-Relabel

```

1 #define MAX_V 1000
2 int N;//valid nodes are [0...N-1]
3 #define INF 1e9
4 //special nodes
5 #define SRC 0
6 #define SNK 1
7 map<int, int> G[MAX_V];
8 //To add an edge use
9 #define add(a, b, w) G[a][b]=w
10 ll excess[MAX_V];
11 int height[MAX_V], active[MAX_V], count[2*MAX_V+1];
12 queue<int> Q;
13 void enqueue(int v) {
14     if (!active[v] && excess[v] > 0) active[v]=true, Q.push(v); }
15 void push(int a, int b) {
16     int amt = min(excess[a], ll(G[a][b]));
17     if(height[a] <= height[b] || amt == 0) return;
18     G[a][b]-=amt, G[b][a]+=amt;
19     excess[b] += amt, excess[a] -= amt;
20     enqueue(b);
21 }
22 void gap(int k) {
23     forn(v, N){
24         if (height[v] < k) continue;
25         count[height[v]]--;
26         height[v] = max(height[v], N+1);
27         count[height[v]]++;
28         enqueue(v);
29     }
30 }
31 void relabel(int v) {
32     count[height[v]]--;
33     height[v] = 2*N;
34     forall(it, G[v])
35         if(it->snd)
36             height[v] = min(height[v], height[it->fst] + 1);
37     count[height[v]]++;

```

```

38   enqueue(v);
39 }
40 ll maxflow() { //O(V^3)
41   zero(height), zero(active), zero(count), zero(excess);
42   count[0] = N-1;
43   count[N] = 1;
44   height[SRC] = N;
45   active[SRC] = active[SNK] = true;
46   forall(it, G[SRC]){
47     excess[SRC] += it->snd;
48     push(SRC, it->fst);
49   }
50   while(sz(Q)) {
51     int v = Q.front(); Q.pop();
52     active[v]=false;
53     forall(it, G[v]) push(v, it->fst);
54     if(excess[v] > 0)
55       count[height[v]] == 1? gap(height[v]):relabel(v);
56   }
57   ll mf=0;
58   forall(it, G[SRC]) mf+=G[it->fst][SRC];
59   return mf;
60 }

```

## 8. Ayudamemoria

### Límites

```
1 #include <climits> //INT_MIN, LONG_MAX, ULLONG_MAX, etc.
```

### Cant. decimales

```
1 #include <iomanip>
2 cout << setprecision(2) << fixed;
```

### Rellenar con espacios(para justificar)

```
1 #include <iomanip>
2 cout << setfill('␣') << setw(3) << 2 << endl;
```

### Leer hasta fin de línea

```
1 #include <sstream>
2 //hacer cin.ignore() antes de getline()
```

```

3 while(getline(cin, line)){
4   istringstream is(line);
5   while(is >> X)
6     cout << X << "␣";
7   cout << endl;
8 }

```

### Aleatorios

```

1 #define RAND(a, b) (rand()%(b-a+1)+a)
2 srand(time(NULL));

```

### Doubles Comp.

```

1 const double EPS = 1e-9;
2 x == y <=> fabs(x-y) < EPS
3 x > y <=> x > y + EPS
4 x >= y <=> x > y - EPS

```

### Límites

```

1 #include <limits>
2 numeric_limits<T>
3   ::max()
4   ::min()
5   ::epsilon()

```

### Muahaha

```

1 #include <signal.h>
2 void divzero(int p){
3   while(true);}
4 void segm(int p){
5   exit(0);}
6 //in main
7 signal(SIGFPE, divzero);
8 signal(SIGSEGV, segm);

```

### Mejorar velocidad

```
1 ios::sync_with_stdio(false);
```

### Leer del teclado

```
1 freopen("/dev/tty", "a", stdin);
```



### File setup

```
1 //tambien se pueden usar comas: {a, x, m, l}  
2 for i in {a..k}; do cp template.cpp $i.cpp; touch $i.in; done
```